MALAYSIAN JOURNAL OF APPLIED SCIENCES 2020, VOL 5 (2): 100-111
E-ISSN:0127-9246 (ONLINE)
http://dx.doi.org/10.37231/myjas.2020.5.2.241
https://journal.unisza.edu.my/myjas

PENERBIT Universiti Sultan Zainal Abidin

MALAYSIAN JOURNAL OF APPLIED SCIENCES
eISSN:0127-9246

ORIGINAL ARTICLE

Marine Macro Debris Transport Based on Hydrodynamic Model Before and After Reclamation in Jakarta Bay, Indonesia

Haifa H. Jasmin[1], Noir P. Purba[2], Widodo S. Pranowo[3], Tri Dewi K. Pribadi[4], Mega L. Syamsudin[5], Yudi N. Ihsan[5*]

[1]Marine Science Program, Universitas Padjadjaran, Kabupaten Sumedang, Jawa Barat 45363, Indonesia
[2]Marine Research Laboratory (MEAL), Universitas Padjadjaran, Kabupaten Sumedang, Jawa Barat 45363, Indonesia
[3]Marine Research Center, Research & Human Resources Agency, Ministry of Marine and Fisheries Indonesia, Kabupaten Sumedang, Jawa Barat 45363, Indonesia
[4]Biology Department, Mathematics and Natural Sciences Faculty, Universitas Padjadjaran, Kabupaten Sumedang, Jawa Barat 45363, Indonesia
[5]Marine Department of Fisheries and Marine Science Faculty, Universitas Padjadjaran, Kabupaten Sumedang, Jawa Barat 45363, Indonesia

[*]Corresponding author: yudi.ihsan@unpad.ac.id

Received: 10/04/2020, Accepted: 28/10/2020, Published: 31/10/2020

Abstract

Jakarta Bay as an area with the densest population in Indonesia is one of the highest contaminated waters in the world including pollution of debris. Reclamation activities in Jakarta Bay will change the water conditions and will also affect the distribution of debris at sea. This study was conducted to determine the movement of the macro debris before and after bay reclamation in Jakarta Bay. The method used is a simulation model using the hydrodynamic and particle trajectory models. The hydrodynamic model used data on wind, tides, bathymetry, and shoreline, while the trajectory model used data on macro debris, debris weight, and debris flux. Hydrodynamics simulations indicate that the reclamation does not change surface current patterns significantly, but resulting in a decrease in flow velocity from around ± 0.002 m/s to 0.02 m/s at some point. The trajectory of debris particles indicates that after reclamation, macro debris tends to accumulate in the eastern region of Jakarta Bay during the rainy season (January) as there are anticlockwise eddy currents. However, debris tend to accumulate in both the western and eastern regions during the dry season (July) due to a clockwise eddy current in the eastern part of Jakarta Bay.

Keywords: Models, reclamation, marine macro debris, Jakarta Bay, trajectory particle

Introduction

Marine debris is a solid persistent object, manufactured or processed by man, directly or indirectly, and found in the marine environment (NOAA, 2016). Marine debris consists of several types, one of which is macro litter measuring 2.5 cm - 1 m long. The exact estimation of the amount of plastics in the ocean is unknown, but the amount of floating debris on the sea level is estimated to be 93,000 tonnes (UNEP, 2009) and nearly 8,200 metric tons of waste were collected along the 40,000 km of coastal globally

(Ihsan et al., 2019). Debris in the ocean may cause death of the microbial life (Derraik, 2002) (Gregory, 2009) (Ihsan et al, 2019), facilitate the spread of invasive species, and release toxic chemicals into the marine environments (Thompson, 2015) (Thompson, 2009) (Lippiatt et al, 2015) (Zettler, 2013) (Kwon, 2015).

Jambeck et al. (2014) stated that Indonesia is the second highest contributor of plastic waste in the world after China. Based on a review by (Pranowo and Purba, 2018) on marine debris in Indonesia, macro and micro debris were found scattering on the surface and in the water column of the sea, on the mangrove ecosystem and on the seabed. Other studies have also indicated that there is a correlation between the distribution of debris in the sea and human activities (Purba et al, 2018). Jakarta Bay is one of most populated coastal areas in Indonesia and may contribute to the release of large amounts of waste into the waters of Jakarta Bay. (Hastuti, 2014) showed that plastic as the main macro waste contributed to 77.7% of the total waste, followed by styrofoam (18.1%), found in the area of Pantai Indah Kapuk, Jakarta Bay.

Reclamation project conducted by the Jakarta government is expected to change the environmental conditions in the waters of Jakarta Bay. Subsequently, this may cause physical changes such as silting, changes in flow patterns, increased solid waste, and changes in the ecosystem, and cause a variety of waste trapped in the waters of Jakarta Bay (Rositasari et al, 2017). Physical changes from reclamation will alter the movement of water particles (Critchell et al, 2015) (Hardesty, 2009) (Politikos, 2017), which later affect the transport of debris in the oceans. Study on macro debris transport before and after reclamation, and changes in the movement of debris found after the reclamation had been reported by reference (Jasmin, 2018). Using a modeling approach, this study focused on the movement of macro debris from the estuary of Jakarta Bay before and after the reclamation. A similar study have been performed by other researchers (Handyman et al, 2019) (Pangestu et al, 2016) (Attamimi et al, 2015), which found that debris movement was influenced by the water hydrodynamics and the types of macro debris used in the model. The results of this study could be used to improve waste management strategy in Jakarta Bay.

Materials and Methods

The study area in this study is the waters of Jakarta Bay, where several rivers enter the bay namely Cisadane, Cengkareng, Angke, Pluit, Sunda Kelapa, Ciliwung, Sunter, Cakung, BKT, Blencong, Cikeas, Ciherang, and Citarum (Figure 1).

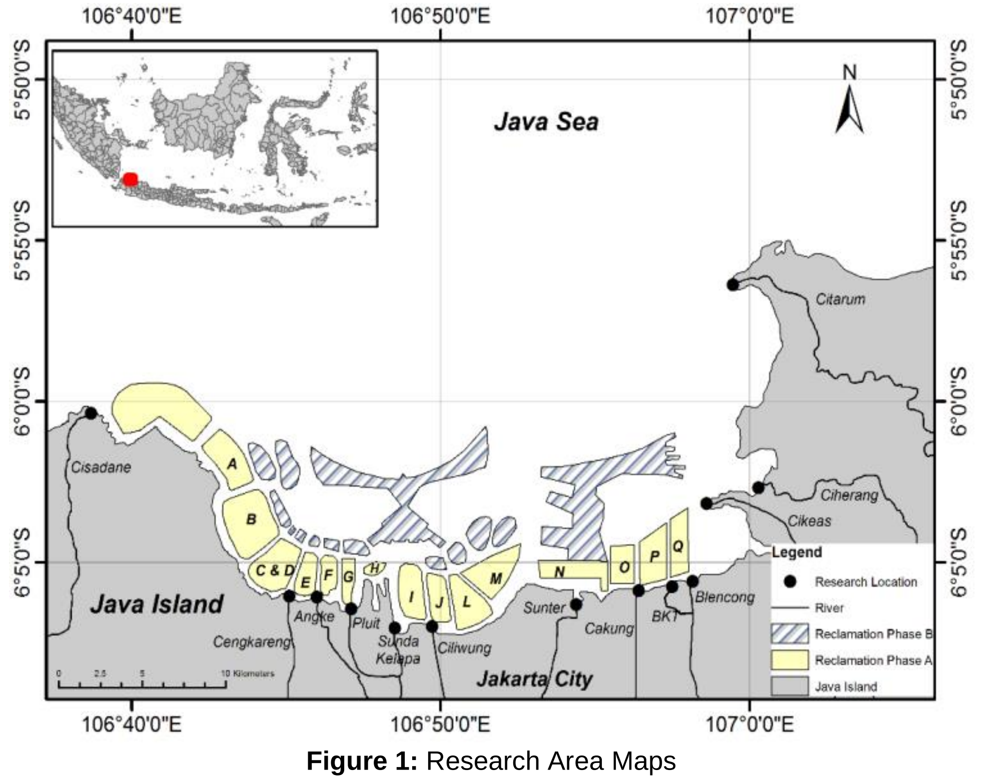


Figure 1: Research Area Maps

The method used in this study is simulation modelling using hydrodynamic and particles trajectory models (Handyman et al, 2019) (Pangestu et al, 2016) (Attamimi et al, 2015). The simulation models were conducted for one-month representing the rainy (Monsoon Transition II and West Monsoon) and drought seasons (East Monsoon and Monsoon Transition I), in January and July respectively (Rositasari et al, 2017). The simulation time is set in 2012 and 2017. Several types of data were used in the simulation model including (i) bathymetric, which was sourced from DISHIDROS bathymetric maps; (ii) tides, from the Prediction of Tidal Height (PTH); (iii) winds, from the European Center for Medium-Range Weather Forecasts (ECMWF) at the resolution of 0.125° x 0.125°, and (iv) streamflow of BBWS (Wulp et al, 2016) And Book II NKLD (Setiawan, 2016). Additional data was used to validate the simulation results namely tidal data from the IOC Sea Level Monitoring from Jakarta Kolinamil station (http://ioc-sealevelmonitoring.org). The tidal type was processed with admiralty method to get the formzahl value, as well as the Root Mean Squares (RMSE) value which was calculated to get the model error (Handyman, 2019) (Pangestu, 2016).

The macro debris sampling was conducted in March 2018, and debris were categorized according to their size, and type of anthropogenic domestic debris by Greenpeace Indonesia in 2016. The following is the classification of domestic debris including bottle caps, shampoo sachets, plastic food wrappers, styrofoam food containers, plastic water bottle 330 mL, plastic bottle 650 mL, plastic bottle 1.5 L, shampoo bottles, plastic, glass beverage bottles, food cans, plastic detergent packaging, and bottles of detergent or other cleaners (which are further subdivided based on weight: 4.55 grams, 12.98 grams, 21.23 grams, 29.45 grams, and 46.03 grams). Scenario simulations include three models namely (i) before the formation of the reclaimed island; (ii) after the formation of the reclaimed island without Garuda Island; and (iii) after a fully-formed Garuda Island. The assumption used in this model is not the degradation of debris annually hydrodynamics waters of Jakarta Bay is not changed, as the cycle and move with the surface current debris (Handyman, 2019) (Pangestu et al, 2016). The analysis was performed so that the hydrodynamic model is able to determine the movement of winds, surface currents, and tidal models, as well as the validation of the tides. Furthermore, simulations were performed using the movement of the macro debris particle trajectory module from the source point which originated from the 13 estuaries presented in Figure 1, as well as the predetermined scenario. The analysis was also conducted for the movement patterns of debris from the source point before versus after the reclamation.

Results and Discussion

Physical parameters

Based on the results of bathymetry data processing, the depth of the waters of Jakarta Bay ranging between 1 and 92 meter. The Jakarta Bay consisted of shallow water around the bay, and several islands that formed the the Seribu Islands. With these topographic variations, depth variations in Jakarta Bay tend to be more on the west than the east side. In general, the depth of the waters of Jakarta Bay ranging from 5 to 32 meters (Rositasari et al, 2017), but other study mentioned that the bathymetry varied between 3 and 29 meter with an average of 15 meter (Rositasari et al, 2017).

The movement of winds in Jakarta Bay is strongly influenced by the monsoons. This study was conducted in January which represents the west monsoon season, and in July which represents the east monsoon season (Figure 2).

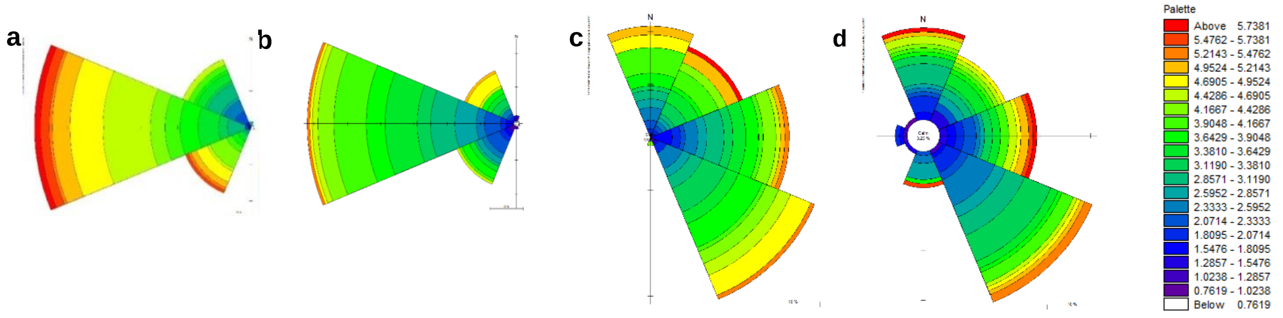


Figure 2: Jakarta Bay Windrose (a) January 2012, (b) January 2017, (c) July 2012, (d) January 2017

The movement of the wind in January 2012 and January 2017 are relatively similar (Figure 2), which is predominantly from the west, with the dominant speed ranged from 5,71 to 6,10 m/s in 2012 and from 4,19 to 5,57 m/s in 2017. This is related to the west season that occurs during December-February, in which the wind is moving from west to east to the area of Java in general.

Just as the movement of the wind in January, the movements of the wind in July 2012 and 2017 tend to be similar. The wind movement is predominantly from the southeast, with the speed rangeing from 3,1 to 3,9 m/s in 2012 and from 2,6 to 2,8 m/s and 3,4 to 3,6 m/s in 2017. The dominant wind speed in January and July in 2012 and 2017 is relatively similar, although the speed in 2012 is faster than in 2017. According to (Lubis and Yosi, 2012), one of the characteristics of the western monsoon is that the rainfall is high and the wind movement is strong at >15 knots, and also characterized by the movement of ocean's waves that leads to the east. The eastern monsoon, on the other hand, is characterized by small and dry wind, and weak ocean waves.

Analysed on tidal patterns based on the PTH data model using the method of admiralty, it is shown that the tidal patterns in the waters of Jakarta Bay, both in January and July, is similar for a single daily uniform pattern (diurnal) with the formzahl value of 3,5. In accordance with previous studies (Yogaswara et al, 2016) (Yuliasari et al, 2012), the waters of Jakarta Bay had a single daily tidal with a range of value between 3,2 and 4.85 formzahl, in which a single daily tidal pattern occur as one high and one low tides in a single day (Yogaswara et al, 2016). The comparison of model tides and IOC Sea Level Monitoring data is presented in Figure 3.

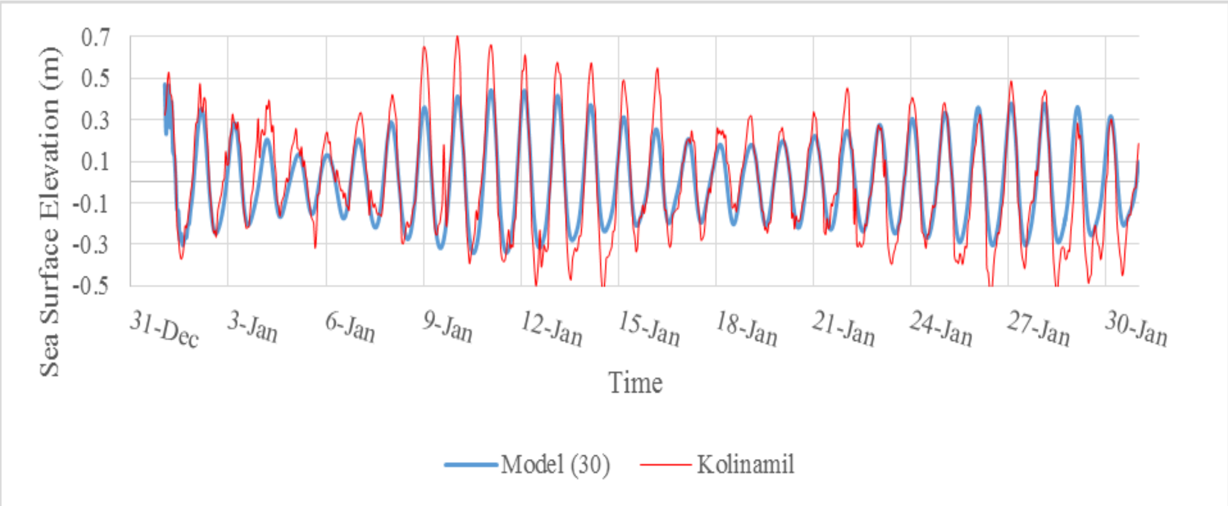


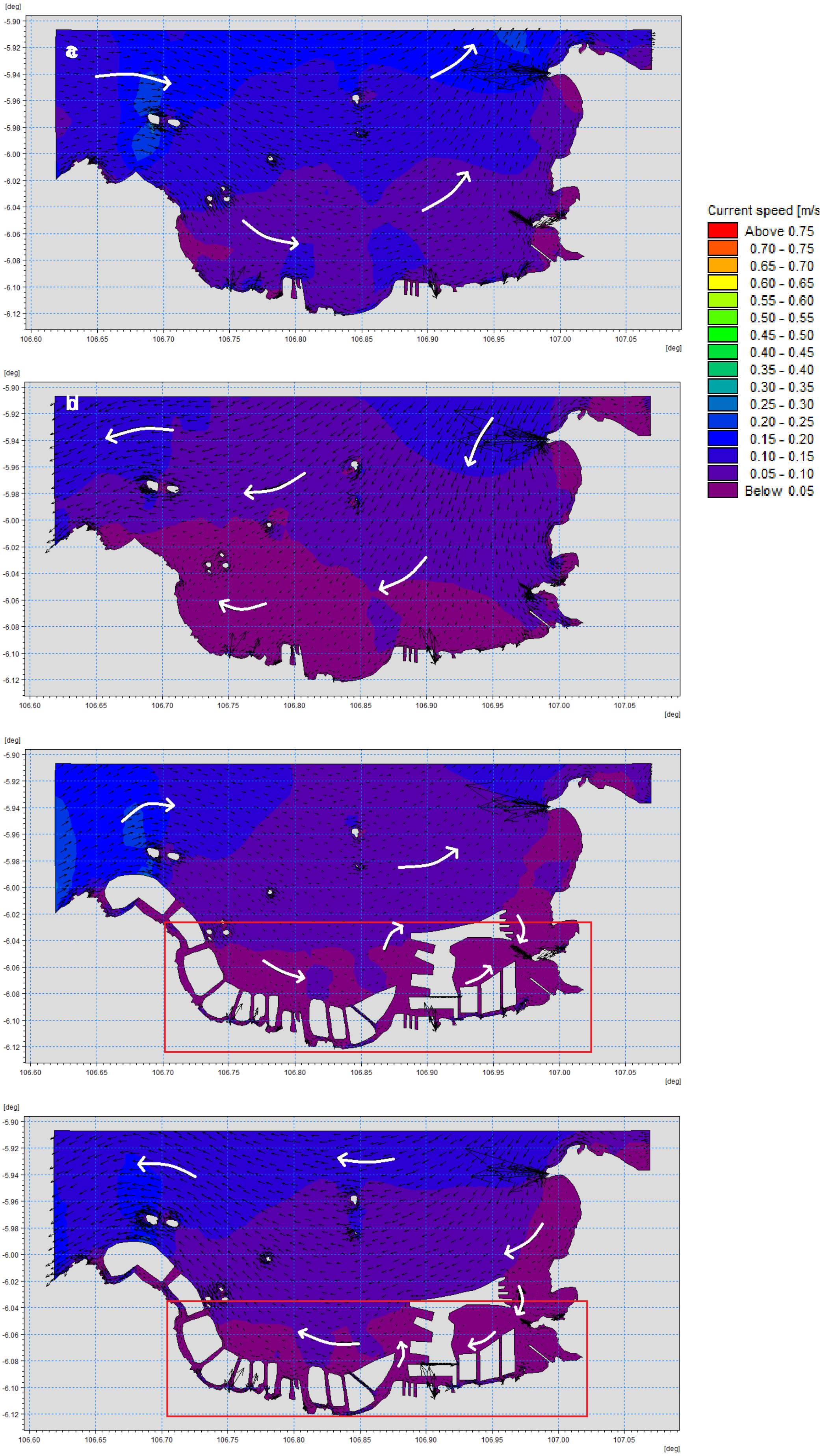
Figure 3: Comparison of Sea Surface Elevation Model and Data from Kolinamil in January 2017

The tidal patterns in January is shown in Figure 3, and the highest tides occur between 00.00 to 05.00 pm, and low tide between 12.00 to 15.00 pm. The tidal patterns in July showed that the highest tides occur between 12.00 to 15.00 pm, and low tide between 00.00 to 02.00 pm.

The tests also indicated that the tides error or RMSE values of the model is equal to 8.5%-12.02%. The RMSE value or value error in January is greater if compared to July, which can be seen from the pattern in Fig. 3 above. According to reference (Veerasamy et al, 2011) a good RMSE values for a good prediction model should be <0.3 or less than 30%. Therefore, our simulation models can be trusted.

Simulation scenario 1, 2, and 3

The hydrodynamics and trajectory of particle simulations for the three scenarios were carried out for one-month, both during the rainy (January) as well as dry seasons (July). Comparison of hydrodynamic simulations was conducted on the speed and the direction of surface currents, while for the trajectory of the particles we studied the movement patterns of the particles. From each estuary, we assumed that one particle come out every hour.


a
b
[deg]
-5.90
-5.92
-5.94
-5.96
-5.98
-6.00
-6.02
-6.04
-6.06
-6.08
-6.10
-6.12
106.60
106.65
106.70
106.75
106.80
106.85
106.90
106.95
107.00
107.05
[deg]
Current speed [m/s
Above 0.75
0.70 - 0.75
0.65 - 0.70
0.60 - 0.65
0.55 - 0.60
0.50 - 0.55
0.45 - 0.50
0.40 - 0.45
0.35 - 0.40
0.30 - 0.35
0.25 - 0.30
0.20 - 0.25
0.15 - 0.20
0.10 - 0.15
0.05 - 0.10
Below 0.05

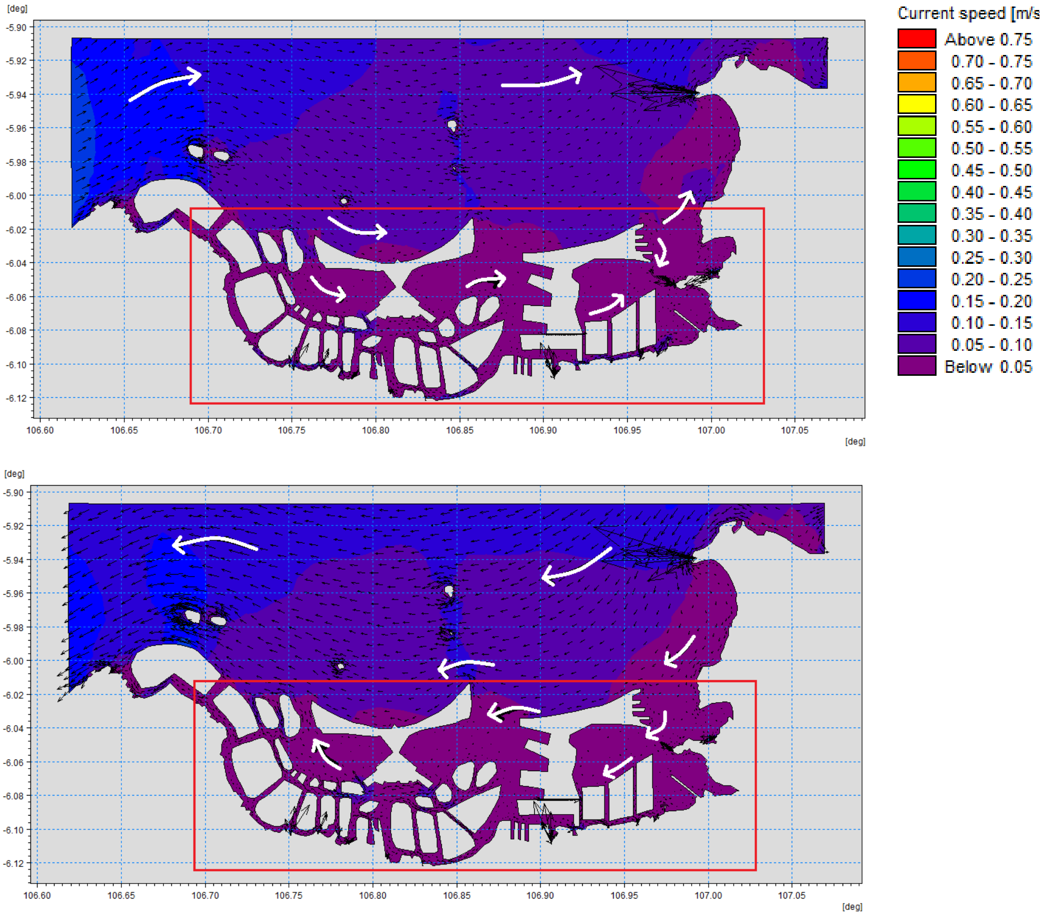
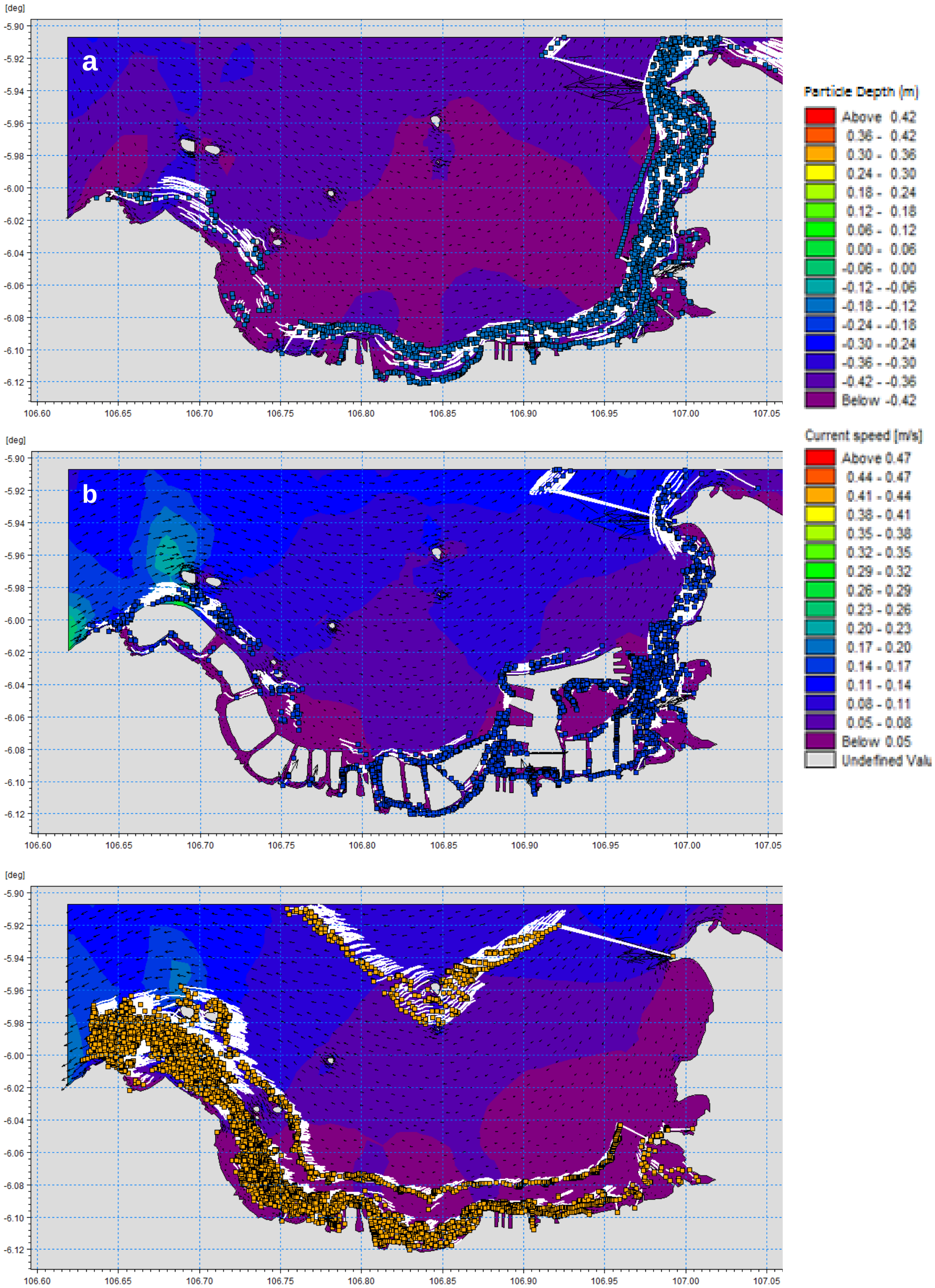


Figure 4: Model of Surface Currents Pattern in Jakarta Bay From Scenario 1 (a) January, (b), July; Scenario 2, (c) January, (d) July; Scenario 3, (e) January, (f) July. The red box shows the region with decreased flow velocity

The movement of surface currents in January is mainly moving eastward, as a result of the movement of winds from west to east (Figure 4), but some times, the surface current is moving from the west to the northwest. In July, the current tends to move towards the west. The direction of the currents is strongly related to the wind and tidalmovements. Based on the picture above (Figure 4), the movement of currents in coastal areas experienced a deflection dependent on the topography of the coastline in the area, as well as the surface current through the islands.

Overall, during the month of January for scenario 1 (Figure 4a), the average flow speed is 0,034 to 0,082 m/s, scenario 2 (Figure 4c) is 0,02 to 0,065 m/s, and the third scenario (Figure 4e) the average surface current speed is 0,025 to 0,066 m/s, while the average flow velocity in July of scenario 1 (Figure 4b) ranged from 0,02 to 0,082 m/s, scenario 2 (Figure 4d) ranges from 0,02 to 0,067 m/s, as well as for scenario 3 (Figure 4f) is from 0,026 to 0,068 m/s.

Comparison of the average surface current speed for some point in scenario 1 January in a row, namely: 0,04 m/s; 0,048 m/s; 0,05 m/s; 0,056 m/s; 0,056 m/s; 0,046 m/s, scenario 2 are: 0,039 m/s; 0,023 m/s; 0,02 m/s; 0,065 m/s; 0,022 m/s; 0,037 m/s, as well as three scenarios are: 0,026 m/s; 0,02 m/s; 0,025 m/s; 0,03 m/s; 0,063 m/s; 0,04 m/s. Comparison of the average flow velocity at some point in scenario 1 July respectively are: 0,082 m/s; 0,023 m/s; 0,026 m/s; 0.061 m/s; 0,03 m/s; 0,036 m/s, scenario 2 are: 0,067 m/s; 0,018 m/s; 0,013 m/s; 0,058 m/s; 0,023 m/s; 0,033 m/s, as well as three scenarios are: 0,068 m/s; 0,023 m/s; 0,026 m/s; 0,05 m/s; 0,03 m/s; 0,035 m/s.


a
b
[deg]
Particle Depth [m]
Above 0.42
0.36 - 0.42
0.30 - 0.36
0.24 - 0.30
0.18 - 0.24
0.12 - 0.18
0.06 - 0.12
0.00 - 0.06
-0.06 - 0.00
-0.12 - -0.06
-0.18 - -0.12
-0.24 - -0.18
-0.30 - -0.24
-0.36 - -0.30
-0.42 - -0.36
Below -0.42
Current speed [m/s]
Above 0.47
0.44 - 0.47
0.41 - 0.44
0.38 - 0.41
0.35 - 0.38
0.32 - 0.35
0.29 - 0.32
0.26 - 0.29
0.23 - 0.26
0.20 - 0.23
0.17 - 0.20
0.14 - 0.17
0.11 - 0.14
0.08 - 0.11
0.05 - 0.08
Below 0.05
Undefined Valu

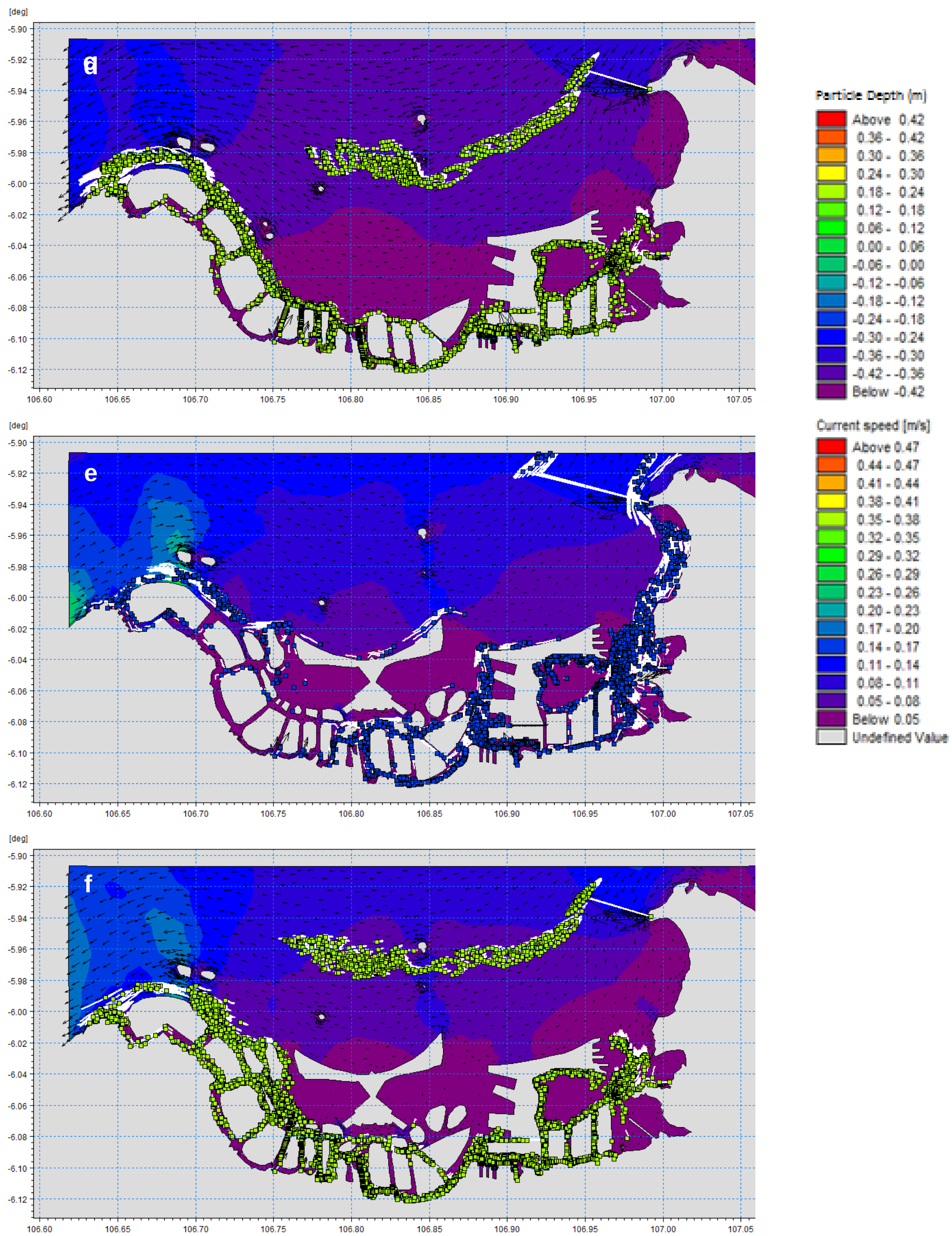


Figure 5: Model of Particle Trajectory in Jakarta Bay From Scenario 1 (a) January, (b), July; Scenario 2, (c) January, (d) July; Scenario 3, (e) January, (f) July

Observation on the particle trajectory simulation was conducted at every seventh day i.e. the 1st, 7th, 14th, 21st, and 28th. The simulation results showed that the movement of debris was influenced mostly by the wind and also by the tidal movements. A simulation in January of scenario 1 (Figure 5a), indicated that within a period of less than 7 to 21 days, the debris from the 13 estuaries are moving eastward away from the Jakarta Bay. In July (Figure 5b), it took longer for debris to travel out from the waters of Jakarta Bay. Debris that originated from Ciliwung and Cengkareng takes up nearly 28 days to move from the waters of Jakarta Bay. Debris from Citarum and Sunter are still in the waters of Jakarta Bay within one-month of the simulation period.

Results from particle trajectory simulation for scenario 2 in January (Figure 5c) showed that macro debris from Sunda Kelapa, Cakung, BKT, Blencong, Cikeas, Ciherang and Citarum are moving away from Jakarta Bay at different periods. Debris particle from other than the above mentioned estuaries did not move away from Jakarta Bay until 30 days of the simulation time. In July (Figure 5d), we found that debris from Cisadane and Cengkareng move out from Jakarta Bay at different travel times, whereas debris from the other 11 estuaries were found in the western part of Jakarta Bay and in the crevices around the reclaimed island. Debris from Ciherang and Cikeas moves into two directions, one that goes through the gaps in the reclaimed island and one that are trapped in the eastern part of Jakarta Bay.

Model debris movement for scenario 3 in January (Figure 5e), showed that moving debris from 13 estuaries partially move away from Jakarta Bay at different travel times i.e. one-month period and partly trapped in the gaps of the reclaimed island. Most of the debris are trapped in the eastern part of Jakarta Bay.

For the simulation in July (Figure 5f), the debris move away from Jakarta Bay within 30 days are those from Cisadane and Cengkareng. Debris from other estuaries are moving and passing through the crevices of the reclaimed island towards different directions, depending on the time and the power of the currents.

The travel distance of the debris particles in January for scenario 1 varies considerably with the farthest reached 63,44 km from Cisadane with a travel time fewer than 21 days; and the closest at 8,64 km from Citarum. Results from simulation in July showed that the farthest distance was 36,97 km from Cikeas, and the closest was 6,34 km from Cisadane. For scenario 2 in January, the farthest was 41,35 km from Citarum and the closest was 6,34 km from Citarum, while in July the farthest mileage is 22,00 km from Cikeas and the closest was 8,64 km from Cisadane. The farthest distance of debris particles in ccenario 3 in January was 48,95 km from Cisadane and the closest was 8,64 km from Citarum, while in July the farthest distance is 28 km from Citarum.

The flow velocity around the 13 estuaries, both in January and July, was higher than any other areas on the coast because of the existing flow of water from several inland rivers. Jakarta Bay stream velocity was categorized as weak pace with an average flow speed between 0 and 4 m/s, this is because the setting of Jakarta Bay as enclosed waters. Previous research has shown that the surface current velocity in Jakarta Bay ranging between 0,034 and 0.277 m/s (Yogaswara, 2016).

The difference between the movement patterns of surface current in the rainy season (January) versus the dry season (July) lies in the direction of the current as well as the current speed, where the speed of flow in July is slower than in January (Atmadipoera, 2015) research showed that the current movement in the west season (monsoon) is faster than east season (summer). In addition, the average speed of wind in January is higher than July, both in 2012 and 2017.

Based on the current speed comparison between scenarios 1, 2 and 3, our study indicated that the pattern of movement in the region has not changed in the near offshore, but there was a change in the reclamation area. In some parts of Jakarta Bay, especially near the reclaimed island, the flow velocity has decreased. The surface current has changed direction at the end point of reclamation and follow the form of reclamation, then follow the pattern of movement of surface currents before reclamation. This is because the surface current is induced or triggered by wind, tide, and the difference in the seawater density (Yuliasari, 2012).

The overall trajectory of the particles of the waste movement in January prior to reclamation is moving to the east, while in July is likely to move to the west. Along with the surface current speed, the movement of the debris particle based on models indicated that in dry season (July), the particles are moving slower than in rainy season, where debris takes longer to exit the waters of Jakarta Bay.

Difference in the direction of particle movement has caused debris to be trapped in the eastern part of Jakarta Bay both in January and July under scenario 1, whereas under scenario 2 and 3 mostly due to differences in flow direction. During rainy season, the surface current gathers in the eastern Jakarta Bay aroung the reclamation area in the opposite directions resulting in an anti-clockwise spin (anticlockwise eddy). In July, however, the current rotates in clockwise direction (clockwise eddy). This is consistent with the results from Atmadipoera (2015) research, which reported that the flow simulation in the Jakarta Bay after reclamation led to the formation in the gap eddys reclamation island, one of them in the eastern part of Jakarta Bay. Other than that, the results of the simulation model of particle tracking from (Norden 2018) also showed that debris in January after reclamation tends to make the debris piled up in the eastern part of Jakarta Bay. Based on this, island reclamation is affecting the movement patterns of the debris particles which may resulted in debris accumulation around the waters of Jakarta Bay.

The movement patterns of macro debris particle from the three scenarios also showed the effects to travel distance of debris particles from each river. The distance tends to decrease with increasing reclamation islands. Travel distance and time of macro debris particle moving away from 13 estuaries varie, especially in scenario 3, because the movement of the debris does not confined to only one direction, but towards different directions when the debris is moving between the gaps in the reclaimed island.

Conclusions

The patterns of surface current movement before and after reclamation have not changed significantly in the offshore area, but a small change has occurred around the reclamation area. The flow velocity decreased from ± 0.002 to ± 0.02 m/s in the area around the reclamated island. The movement of macro debris in January was influenced by the tides which are primarily moving towards the eastern part of Jakarta Bay, whereas the tides in July tend to move towards the west part of Jakarta Bay at a slower pace than in January.

Results from model simulation of the particle trajectory from three different scenarios showed there are changes in the movement patterns of macro debris particles. In January, the particle tends to be trapped in the eastern part of Jakarta Bay and in some areas of the reclaimed island due to the anti-clockwise eddy. In July, however, the particles are partially trapped in the western region of the reclaimed island and partly in the eastern part of Jakarta Bay due to the clockwise eddy.

Acknowledgments

The authors would like to thank the Laboratory of Marine Research Laboratory (MEAL), Universitas Padjadjaran, and the Laboratory Center for Marine Research, Research & Human Resources Board, (Ministry of Marine and Fisheries of Indonesia) who has facilitated the author during the research process, Mr. Ibnu Faizal, as well as colleagues who participate in helping during the research process.

References

Atmadipoera AS, & Adhyatma D. “3D Numerical Modeling Study of Circulation Flow In Gulf Jakarta: Before And After Reclamation”, *Scientific IPB Repository*, No.839, (2015).

Attamimi A, Purba NP, Anggraini SR, and Harahap, SA, “Investigation of *Marine Debris in Kuta Beach*, Bali”, In: Suhartanto E, Sudarsono PT, WWS, A, Andawayanti U, Hidayat F, Susilo GE (eds), *Proceedings of Environmental Engineering and Water Technology, Integrated Water System and Governance (Malang, East Java, Indonesia)*, (2015), pp. C1-7.

Critchell K, Grech A, Schlaefer J, Andutta FP, Lambrechts J, & Wolanski E, “Modelling the fate of marine debris along a complex shoreline: Lessons from Great Barrier Reef”, *Estuarine, Coastal and Shelf Science*, (2015), pp.414-426.

Derraik J, “The Pollution of the Marine Environment by Plastic Debris: a review”, *Marine Pollution Bulletin*, Vol.44, No.9, (2002), pp.842-852.

Gregory M, “Environmental Implications of Plastics in the Marine Debris Settings-entanglement, ingestion, Smothering, Hangers-on, Hitch-hiking, and alien invasions”, JOURNA: NAME?, Vol.364, No.1526, (2009), pp.2013-2025.

Handyman DIN, Purba NP, Pranowo WS, Harahap SA, Dante IF, and Yuliadi LP, “Patch Microplastics Based on Hydrodynamic Modeling in the North Indramayu, Java Sea”, JOURNAL NAME?, Vol.28, No.1, (2019), pp.1-8.

Hardesty BD, “Model Using Numerical Simulations to Improve the Understanding of Micro-plastic Distribution and Pathways in the Marine Environment”, *Frontiers in Marine Science*, Vol.4, No.30, (2009), doi: 10.3389/fmars.2017.00030

Hastuti AR, “Marine Spatial distribution Debris in Pantai Indah Kapuk Mangrove Ecosystem Jakarta”, Vol.29, (2014).

Ihsan, YN., Subiyanto, Pribadi TDK, Schulz C, Nitrogen assimilation potential of seaweed (*Gracilaria verrucosa*)in polyculture with Pacific white shrimp (*Penaeus vannamei*). AACL Bioflux. 12 (51-56). (2019)

Jambeck J, Geyer R, Wilcox C, Siegler T, Perryman M, Andrady A, Narayan R, “Plastic waste inputs from land into the ocean”, *Marine Pollution*, (2014), pp.768-770.

Jasmin HH, “Model Transpor Sampah Makro dari Muara Sungai Sebelum dan Sesudah Terbentuknya Pulau Reklamasi di Teluk Jakarta”, Ind. thesis, Universitas Padjadjaran, West Java, Indonesia, Aug. (2018).

Kwon BK, “Global styrene oligomers as new monitoring chemical contamination from plastic polystyrene Marine pollution”, (2015).

Lippiatt S, Opfer S, & Arthur C, “Marine Debris Monitoring and Assessment”, Vol.46, (2013).

Lubis A, & Yosi M, “Maritime Meteorological conditions and Oseanogradi in the Waters Around Kotok, Kepulauan Seribu”, *Journal of Tropical Marine Science and Technology*, Vol.4, (2012), pp.24-34.

Norden A & Karlsson S, “Optimizing the placement of the cleanup systems for plastic marine debris: A multi-objective approach”, No.58, (2018).

National Oceanic and Atmospheric Administration (NOAA), *Marine Debris Program*, (2016).

Pangestu IF, Purba NP, and Syamsudin ML, “Condition Microplastic in Indramayu, West Java Waters”, In: Afrianto E, Yustiati A, Hasan Z, Anna Z, Andriani Y, Rizal A, and Syamsudin ML (ed.), *Proceedings of the National Seminar on Fisheries and Maritime Affairs: Synergy of Technology, Law, and Policy Division Fisheries and Marine Sciences Towards Food Sovereignty in the Age of MEA (Bandung, Indonesia)*, (2016), pp.382-390.

Politikos DV, “Modeling Fate and Distribution of Floating Particles Litter in the Aegean Sea (E.Mediterranean)”, (2017). doi: 10.3389/fmars.2017.00191.

Pranowo WS & Purba NP, “A Review of Marine Debris in Indonesia- (revised ADS, WSP, AH) -2”, (2018). doi: 10.13140 / RG.2.2.33240.60161

Purba NP, Dewanti LP, & Faizal I, “Distribution of Macro Debris at Pangandaran Beach, Indonesia”, *World Scientific News*, No.103, (2018), pp.144-156, available online: https://www.researchgate.net

Rositasari R, Puspitasari R, Nurhati IS, Purbonegoro T, & Yogaswara D, “Research Review 1970-2015 Oseanografi in Jakarta Bay. 5 Decade LIPI in Jakarta Bay”, (2017), pp.89-102. ISBN: 978-602-6504-07-4

Setiawan A, “Simulation Model Hydrodynamic and Thermal Dispersion in Jakarta Bay Pre- and Post-reclamation 17 Island”. Vol.1, No.1, (2016). doi: 10.13140/RG.2.2.223290.08642

Thompson RC & Amaral-Zettler LA, “The ecological impacts of marine debris: unraveling the demonstrated evidence from what is perceived”, *Ecology*, Vol.97, (2015), pp.302-312.

Thompson RM, “Plastics, the environment and Human Health: sunsesus surface current and future trends”, Vol.364, (2009), pp.2153-2166.

UNEP, “Marine Litter: A Global Challenge”, (2009), 232.

Veerasamy R, Rajak H, Jain A, Sivadasan S, Varghese CP, & Agrawal RK, “Validation of QSAR Models - Strategies and Importance”, *International Journal of Drug Design and Discovery*, Vol.2, No.3, (2011), pp.511-519.

Wulp SA, Dsikowitzky L, Hesse KJ, & Schwarzbauer J, “Master Plan of Jakarta, Indonesia: The Giant Seawall and the need for structural treatment of municipal wastewater”, *Marine Pollution Bulletin,* No.110, (2016), pp.686-698. available online: http://dx.doi.org/10.1016/j.marpolbul.2016.05.048

Yogaswara GM, Indrayanti E, & Setiyono H, “Surface flow patterns in the waters of Tidung, Thousand Islands, Jakarta on transition season (March-May)”, *Journal of Oceanography*, No.5, (2016), pp.227-233, available online: http://ejournal-s1.undip.ac.id/index.php/jose

Yuliasari D, Zainuri M, & Lewis DN, “Study of Flow Pattern in Marina Ancol and Its Effect on Reclamation Plan”, *Bulletin Oceanographic*, (1), (2012), pp.1-9.

Zettler EM-Z, “Life in the Platisphere: Microbial Communities on Marine Plastic Debris”, *Evnironment Science Technology*, Vol.47, No.13, (2013), pp.7137-7146.

How to cite this paper: Haifa H. Jasmin, Noir P. Purba, Widodo S. Pranowo, Tri Dewi K. Pribadi, Mega L. Syamsudin, Yudi N. Ihsan (2020). Marine Macro Debris Transport Based on Hydrodynamic Model Before and After Reclamation in Jakarta Bay, Indonesia
Malaysian Journal of Applied Sciences, 5(2), 100-111.